Learning science through creating simple animations in both primary and secondary schools

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ABSTRACT Creating a short 'claymation'-style or drawn animation in a school science classroom using a digital or mobile phone camera, Plasticine® modelling clay and free software such as *Windows Moviemaker* is now possible within one or two 1-hour lessons. This article reports a project that explored working with four science teachers and their classes to pilot the creation of animations as a means of learning about the largely invisible concepts currently being taught. Nearly everyone enjoyed making the animations in school and the finished animations, while rudimentary, enabled discussion and reinforcement of the science concepts being animated. Students from all classes reported that the discussion during the making of the animation and viewing others' work was helpful in developing their understanding.

Animation as a way to visualise science processes

Learning is complex, and learning science particularly so. Many students perceive science to be difficult and inaccessible (Simon and Osborne, 2010), which may well be because much of science learning is concerned with understanding largely invisible processes that are too slow, too small or on too large a scale to be readily observed (Webb, 2010). The equation representing a chemical reaction such as $2H_2 + O_2 \rightarrow 2H_2O$ describes unseen processes, including atom rearrangement with bonds breaking then forming. Krajcik (1991) points out that students often struggle to understand representations such as this, and teachers report using models, either their own or asking the student to create one, to make the invisible visible or the abstract concrete, which is key to science education (Justi and Gilbert, 2002). Rotbain, Marbach-Ad and Stavy (2008) have reported that using computer animations of DNA replication, transcription and translation with students aged 17–18 effectively offered them an accurate, rich picture of the dynamic nature of these processes, which enabled a significant improvement in students' understanding.

This article focuses on activities in which students create stop-frame animations using Plasticine® modelling clay, laptop computers and drawing tools, sometimes known as 'claymations'. For example, students can use Plasticine to model the atoms in the original molecule and in the different molecules resulting from a reaction, capture these changes on camera and create an organised sequence to play back to others. The unseen processes referred to by Krajcik (1991) are visualised, emphasised and reinforced by creating such an animation. Thus, multiple, linked representations of the process being animated combine to enhance understanding, with meaning building from one representation to the next (Hoban and Nielsen, 2013). This emphasis on building resonates with the constructivist approach to learning described by Good and Brophy (1994), which involves learners constructing their own meaning and manipulating knowledge by making connections between stored and new information – a process that is enhanced by social interaction and through authentic tasks. However, we should be cautious, as earlier work on the use of computer animations in teaching reported mixed effectiveness in supporting learning. Ainsworth (2008) noted that animations can detract from, as well as engender, learning, and Sutherland *et al.* (2004) pointed out that, when using technology-supported learning activities, the teacher has a critical role in creating a culture for student learning.

Previous research into the use of 'claymation' in science teaching has largely centred on initial teacher education (Hoban and Nielsen, 2013). In this article we provide an initial insight into students' learning from the different experiences involved in creating animations and how they view their effectiveness at enabling understanding. Research questions for this small-scale study were as follows.

- Which activities within the process of creating animations motivate students of different ages towards learning science in this way?
- Which activities within the process of creating animations in science lessons are perceived by students of different ages to support their understanding?
- What are the teachers' views of creating animations as a science teaching strategy with students of different ages (8–9, 12–13, 15–16 and 16–17)?

Method

Study design

Quantitative data on students' motivation towards making animations and their perception of whether this supported understanding were obtained through use of closed questions in a survey. Further qualitative data came from semi-structured teacher interviews and non-participant observation during the science lessons. The science concept to be taught through the making of animations was chosen by the class teacher.

Participants

Four teachers were recruited by contacting local teachers known to be interested in research opportunities. Each teacher introduced animation creation as a means of teaching and learning within the observed time frame to a single class. The class sizes and concepts taught are shown in Table 1. Participants comprised students from four classes in different schools and their teachers. All schools were sited in populous, urban locations and all classes were mixed gender. All teachers had more than 3 years' teaching experience: two secondary science teachers specialised in biology and one in physics; the primary school teacher was a science specialist. Only the year 12 teacher had previously used animation in science teaching.

Instruments

The research instruments included a student questionnaire survey, presented on paper or online, and a semi-structured teacher interview schedule. Permission was obtained from students to use their animations and survey responses for the research project. The survey asked students to rate their experiences while creating animations on a 7-point scale (where 1 represented 'not at all' and 7 represented 'very, very much') firstly according to enjoyment and then again according to support with understanding the concept being taught. The list of experiences or possible activities was based on Hoban and Nielsen's (2013) stages of creating an animation but was adapted as the participant teachers focused on various aspects of animation creation, meaning that not all classes participated in all possible activities. The final list comprised: researching the topic; storyboarding; making (modelling or drawing); taking photos or finding images; putting pictures/slides in order; adding titles; adding a commentary; adding sound effects or music; talking during planning and making; seeing the finished animation; seeing the others' animations; and discussing the others' animations. Interview questions for teachers addressed their

Table 1 Overview of the participating classes

School	Class	Age	Number of students	Time available	Concept
Local government maintained, 7–11 primary	Year 4	8–9	26	3 hours	Filtering and sieving
Government maintained academy, 11–18 secondary	Year 8	12–13	30	1 hour	Circulatory and respiratory systems
Independent, 13–18 secondary	Year 11	15–16	25	10 hours over 6 weeks	Physics GCSE revision (student choice of topic)
Independent, 13–18 secondary	Year 12	16–17	9	1 hour 40 minutes	Transport across cell membranes

lesson preparation, perceptions of learning that took place, and any concerns about teaching via animations.

The researcher attended all lessons as a non-participant observer. Students completed the survey immediately after completion of the animations. The teacher was interviewed face to face once the lesson was over, except in one case where this was impossible because of constraints on the teacher's time and the interview questions were answered via email.

Data analysis

The quantitative data on students' motivation towards the activity and how much they believed it supported their understanding of the concept being taught were analysed by calculating the percentage of the highest ratings (6 or 7) awarded to each activity. This was to show how highly the different learning activities were rated (see Table 3, for example). The interviews with teachers were transcribed and then subjected to thematic content analysis (Braun and Clarke, 2006).

Procedure

Teachers managed the lesson or sequence of lessons on animation individually, as shown in Table 2. However, all teachers presented animation as a method for consolidating students' learning of their current science topics.

Year 4 students (aged 8–9) whose lesson was planned to take a morning (3 hours) were tightly managed by their teacher, with demonstrations of how to use the equipment and specific times allocated for storyboarding, taking photos, uploading and ordering images, and producing the animation. Students worked in groups of three or four, with one student solely responsible for the camera.

The year 8 teacher allowed students (aged 12–13) to choose which software and tools they wished to use, relying on their knowledge of animation acquired in information and communication technology (ICT) lessons to animate concepts from the 'Going for Gold' topic in the school scheme of work. The concepts were also chosen by the students and covered the structure and function of either the lungs or the

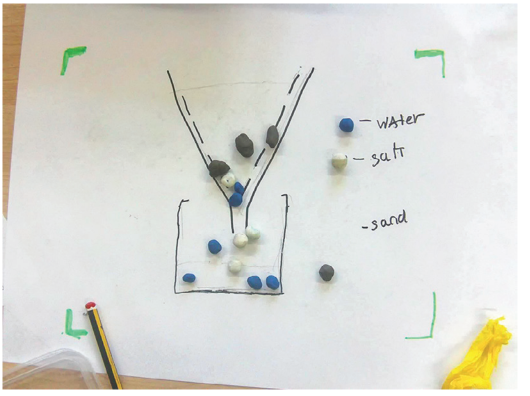

Figure 1 Frame from a year 4 animation on the concept of filtering and sieving

Figure 2 A year 8 student working on their animation of the lungs

Table 2 The different concepts chosen and tools used

Age	Concept taught	Tools used to capture and animate images
8–9	Filtering and sieving, particle size (see Figure 1)	*PowerPoint* with one image per slide and digital cameras
12–13	Circulatory and respiratory systems (see Figure 2)	Choice between using *PowerPoint* with cameras, edited images sourced from the internet or using *Serif Draw Plus* or *Pivot* to draw freehand
15–16	Physics revision (see Figure 3)	*Windows Moviemaker* and digital cameras
16–17	Transport across cell membranes (see Figure 4)	*Flip* video cameras

heart. Students worked in pairs for 1 hour; this was the only group whose animations were not played back to the class for discussion.

Year 11 students used animation creation to revise for their physics General Certificate of Secondary Education (GCSE; the national exam taken by 16-year-olds in the UK, except in Scotland). In the 10 hours available, students created detailed animated stories with narrations to show their understanding of a concept of their choice from the GCSE syllabus. The concepts chosen were planetary orbitals, the Big Bang, terminal velocity, electrical safety, stability, deceleration and transfer of momentum, angular momentum, and nuclear fission.

The year 12 biology students (aged 16–17) worked in groups of three in a single 100 minute lesson using *Flip* video cameras. Rather than creating stop-frame animations, the students used the camera to capture the movement of Plasticine models over a hand-drawn background to demonstrate the biological structures and physical processes that enabled transport of proteins, sugars and fluids across plant cell membranes.

Figure 3 Frame from a year 11 animation to revise a GCSE physics topic

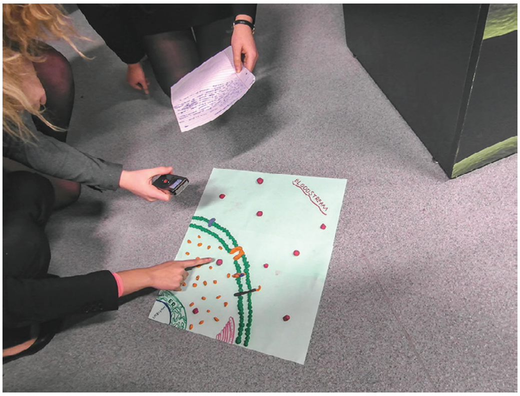

Figure 4 Year 12 students working on their animations of transport across plant cell membranes

Results

Completed questionnaires were received from all 26 year 4 students, 26 of 30 year 8 students and all nine year 12 students; 12 of the 25 year 11 students completed the online version of the survey. Results are tabulated by class (Tables 3–6). The tables show the numbers of students who awarded each activity a 6 or 7 for 'enjoyment' and 'understanding'. Highest 'understanding' values are listed first. The frequencies shown vary because not all students undertook all activities, and responses were voluntary.

All the groups of year 4 students (aged 8–9) successfully created short animations that showed smaller particles moving through a filter or sieve and the larger particles being retained. Table 3 shows that the 38% of students who reviewed the order of images captured for their animation rated it most

Table 3 Year 4 students' ratings for enjoyment and understanding

Activity	Frequency	% rated 6–7 for enjoyment	% rated 6–7 for understanding
Ordering images*	10	60	78
Seeing others' animations	25	84	76
Discussing others' animations*	9	56	75
Making (modelling/drawing)	25	88	72
Seeing finished animation	23	65	67
Storyboarding	24	46	65
Talking during task	22	64	64
Taking photos	25	77	61
Adding sound effects or music*	11	64	45
Adding titles	22	64	43

*reported on by less than half the group who completed the survey

Table 4 Year 8 students' ratings for enjoyment and understanding

Activity	Frequency	% rated 6–7 for enjoyment	% rated 6–7 for understanding
Talking during task	18	56	69
Making (modelling/drawing)	19	47	53
Adding sound effects or music*	2	0	50
Discussing others' animations*	10	20	50
Ordering images	13	38	38
Seeing finished animation	24	54	37
Adding titles	14	36	36
Taking photos	13	31	31
Seeing others' animations	20	55	22
Storyboarding*	5	60	20

*reported on by less than half the group who completed the survey

highly for supporting their science understanding, with 78% rating it as 6 or 7, alongside seeing others' animations (76%), discussing (75%), and making (modelling or drawing) (72%).

Discussing others' animations was also reported as strongly supporting understanding by half of the year 8 students (aged 12–13) (Table 4). More of this group (69%) rated talking with peers during the task most strongly for supporting understanding, followed by making (modelling or drawing) (53%). All their animations were completed but varied in quality. Particularly effective animations showed the passage of a red blood cell through the heart, the structures involved in breathing and the damaging effects of cigarette smoke on the lungs.

Year 11 students (aged 15–16) noted how the animation creation activity supports discussion. Table 5 shows that the three activities they reported most frequently to be supportive of understanding science were: discussing others' animations (60%), talking during task (42%) and researching the topic (42%). Animations made by this class were much more detailed, and several incorporated human characters such as 'Big Head Ned' who had issues with stability, an unfortunate type who wired up his kitchen appliances incorrectly (see Figure 3) and a sky diver who reached terminal velocity.

Table 6 shows that the year 12 students (aged 16–17) reported ordering the images (100%), talking during the task (50%) and discussing others' animations (50%) as being of most benefit in supporting their understanding of how different subcellular structures enable passive and active transport across cell membranes in plant cells.

Thus, to answer the first research question (which activities within the process of creating animations motivate students of different ages towards learning science), seeing others' finished

Table 5 Year 11 students' ratings for enjoyment and understanding

Activity	Frequency	% rated 6–7 for enjoyment	% rated 6–7 for understanding
Discussing others' animations	10	60	60
Talking during task	12	67	42
Researching the topic	12	25	42
Adding a commentary	8	13	38
Seeing others' animations	11	82	36
Seeing finished animation	12	83	25
Ordering images	8	25	13
Adding sound effects or music*	5	60	0
Making (modelling/drawing)	12	50	0
Storyboarding	10	30	0
Adding titles*	4	25	0
Taking photos	11	9	0

*reported on by less than half the group who completed the survey

Table 6 Year 12 students' ratings for enjoyment and understanding

Activity	Frequency	% rated 6–7 for enjoyment	% rated 6–7 for understanding
Ordering images*	2	0	100
Talking during task*	4	50	50
Discussing others' animations*	4	25	50
Making (modelling/drawing)	9	33	33
Seeing others' animations	8	50	25
Taking photos	8	13	25
Storyboarding*	2	50	0
Seeing finished animation	7	29	0
Adding titles*	3	0	0
Adding sound effects or music	0	0	0

*reported on by less than half the group who completed the survey

animations clearly motivated students of all ages. The youngest students (aged 8–9) most often enjoyed making (modelling or drawing), and the year 11 students (aged 15–16) most enjoyed seeing their own finished animations. Students who made storyboards in the other two groups (year 8 (aged 12–13) and year 12 (aged 16–17)) reported this as enjoyable most often; however, not many undertook this task. One student in each of year 4 and year 8 reported disliking making animations; both had been assigned to non-friendship groups.

With respect to the second research question, activities centred on discussion were perceived by students of all ages to support their understanding – either talk during the task or teacher-led discussion during display of the finished animations, both of which scored consistently highly in all four age groups.

Three themes emerged from teacher post-lesson interviews: concerns, teaching strategies used and recommendations for other teachers.

Concerns

Teachers were concerned with the students' ability to use the animation tools (cameras, laptops and software). The year 8 teacher noted: '*Once the children are confident with the equipment to animate, I can see there being a pure science objective, and animation can be used as a tool.*'

Teachers also expressed concern about the necessary preparations, which included checking that batteries were charged, that sufficient computer memory for processing and hard drive space for storing the images were available, having a go themselves at making an animation, and awareness of students' existing understanding of the topic to be animated.

Teaching strategies

Creating animations was presented as a teaching and learning strategy for consolidation or revision of a topic following delivery using traditional methods. All four teachers noted that making animations provided opportunities to question students' about their science knowledge and understanding, for example '*to get students to talk through their models, bringing out the science*' (year 8 teacher) and '*to check science words are used appropriately*' (year 4 teacher).

This led to reflections about making animations as a teaching strategy that enables opportunities for assessing learning and identifying student misconceptions: '*You can do exercises like this to make them think about the shape, to help them understand the shape of the proteins, think about what they actually look like in 3-D and actually tie structures to the functions more successfully*' (year 12 teacher).

Teachers also noted consolidation through multiple opportunities for learning. When asked whether all the stages of making an animation shown in Tables 2–5 were important to learning, three of the four agreed with the year 12 teacher's report: '*I think they are all important. The first stage is modelling their understanding and gives a chance to correct anything. If you listen to the groups they will help each other "What's that?", "Which way up should this be?".* [...] *And yes, the other stages are important as well. You have to be able to see what they have done and allow for comments, say "that was good" or "change that bit".*'

The year 8 teacher focused on making models and background drawings: '*I think the most important part of the whole thing is the doing of* *it, to work the animation, looking it through, as long as it is correct.* [...] *Doing it is a lot more important than anything else. They like to see each other's but it is not nearly as important in terms of their learning*'.

All four teachers highlighted peer learning as a relevant teaching strategy for animation work. The year 11 teacher noted: '*The groups discuss concepts and ask each other if they don't understand an idea fully.*'

The year 4 and year 8 teachers mentioned forming mixed-ability student groups to support peer learning, and the year 8 teacher highlighted the importance of making sure that peer learning opportunities are managed productively, ensuring that all resources are shared equally among students.

Recommendations for other teachers

Teachers suggested new tools, for example: '*Might be easier with student iPads*' (year 11 teacher) and '*They* [the ICT Department] *are supposed to be getting some animation software*' (year 8 teacher).

There was agreement that all age and ability groups should be included: '*All of key stage 2 children* [ages 7–11] *could produce an animation to show a science process.*' (year 4 teacher) and '*I've done animation with sixth form, done it with year 9s, with year 10s* [...] *I don't think it makes much difference*' (year 8 teacher).

The year 4 teacher also noted the importance of managing students' expectations: '*They will probably not be that pleased with the end result* [...] *Therefore, the production of the animation must not be the end in itself. Children must see the value of the process and understand the learning journey they have to do.*'

Thus, to answer the second research question, the teachers' views of using the creation of animations as a science teaching strategy are largely positive, with no major differences among students of different ages, other than the complexity of the concept being animated. However, the teachers highlight the amount of preparation required, which may include the need to teach students to use cameras and software.

Discussion

All students in the four lessons observed successfully produced an animation in the available time. All teachers reported that the activity reinforced students' science learning and was widely enjoyed. Creating the representations engaged all student groups. While this study supports the findings of Hoban and Nielsen (2013) in that teachers viewed all stages in producing an animation as important to learning, only teachers of year 4 and year 11 really engaged with storyboarding. Hoban and Nielsen (2013) view storyboarding as the first stage in a semiotic progression; however, two of the three groups of year 12 students (aged 16–17) did not complete their storyboards, moving quickly on to manipulating Plasticine as they planned their animation. They reported that this was more helpful to their thinking about and discussing the science process they were aiming to represent.

Teachers reported peer-learning as important, together with planning ahead to create productive student groups. This helped ensure that discussion, both during the task and of the final products, was rated by students as the activity that was most helpful to their understanding of the underpinning science. The emphasis that both teachers and students reported on social interaction, building representations and manipulating the resulting models for filming strongly associates the process of making animations with both constructivist learning opportunities (Good and Brophy, 1994) and the importance of enabling on-task talk in the science classroom (Mortimer and Scott, 2003).

The activity also occasionally exposed students' weak understanding, giving teachers opportunities to address errors. The models and video being made provide external representations that can support teachers in assessing students' learning. This confirms the findings of Loughran *et al.* (2012) that making an animation shows up alternative conceptions effectively and allows students a safe environment in which to talk through ideas.

Two of the activities involved in making animations did not always impact on learning as anticipated. These were sequencing images for the animation and playing back the resulting animations to the class. Most groups took their photos in the planned order, and the year 8 teacher did not allow time for discussion of the science content of the completed animations. However, assigning a longer period of time to making the animations enhanced the opportunities for students to display their creativity. Year 11 students in this study, for example, developed storylines featuring a main character to illustrate science concepts.

Conclusion

Making simple animations appears to enable constructivist learning opportunities through social interaction, both among students and between students and their teacher, and through authentic tasks. This can now be done within an hour in a science classroom equipped with digital cameras and laptops or tablet computers. However, this was a small-scale study that did not assess individual students' learning.

Recommendations for further research include evaluating the learning involved, how that learning develops both in and between the different stages of creating the animation, and investigating the role of creativity in the process.

Recommendations from the teachers involved included ensuring that:

- Plasticine models needed for filming are planned before starting;
- cameras are charged or spare batteries made available;
- the default image quality matches the processing power of the computer network.

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